High Rate Deposition of nc-Si:H Solar Cells and Its Application in a-Si:H/nc-Si:H Multi-Junction Structure

Guozhen Yue, Baojie Yan, Jeffrey Yang,

and Subhendu Guha

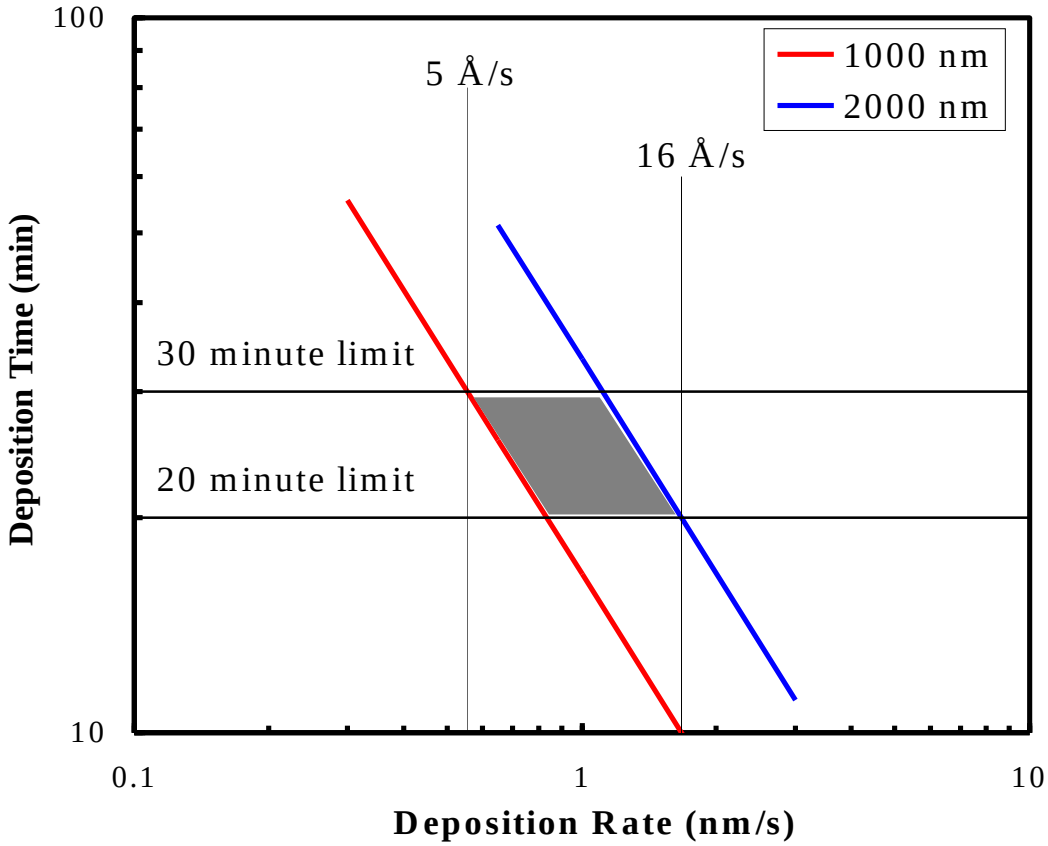
United Solar Ovonic Corporation

Troy, Michigan

UNI-SOLAR®

Outline

1. Estimation of the required deposition time for manufacturing
2. Existing method for high rate deposition and our approaches with previous results
3. Current statues for nc-Si:H single-junction and a-Si:H/nc-Si:H double-junction solar cells
4. Summary and future work



Deposition time for nc-Si:H films as a function of the deposition rate. The shaded region represents the field of interest for solar cell production.

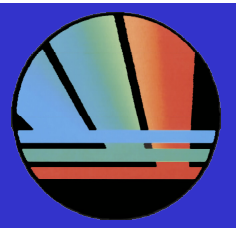
Existing method for high rate deposition

VHF glow discharge: 60-110 MHz

- Advantage: high rate with low ion bombardment
- Potential problem: Uniformity

RF glow discharge with high pressure and high power

- Advantage: high rate with low ion bombardment
- Potential problems: Uniformity, powder formation, narrow spacing between electrodes



VHF with high pressure and high power

- Advantages from both VHF and high pressure, but challenges also add together

Hot-wire

- High deposition rate with no ion bombardment
- Only limited positive results in the literature

UNI-SOLAR®

Approaches at United Solar

Modified-VHF

1. 12.5%: a-Si:H/nc-Si:H double-junction structure
2. 13.8%: a-Si:H/a-SiGe:H/nc-Si:H triple-junction structures (bottom cell deposition time of 50 minutes)

RF glow discharge with high pressure and high power

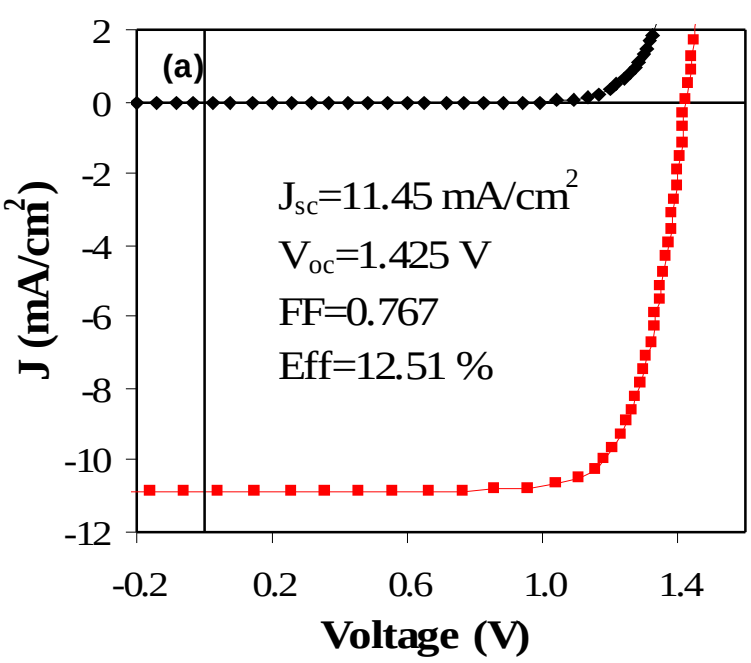
1. 12.3%: a-Si:H/nc-Si:H double-junction structure(bottom cell deposition time of 60 minutes)
2. Currently, we are studying large-area deposition (G.G. will present)

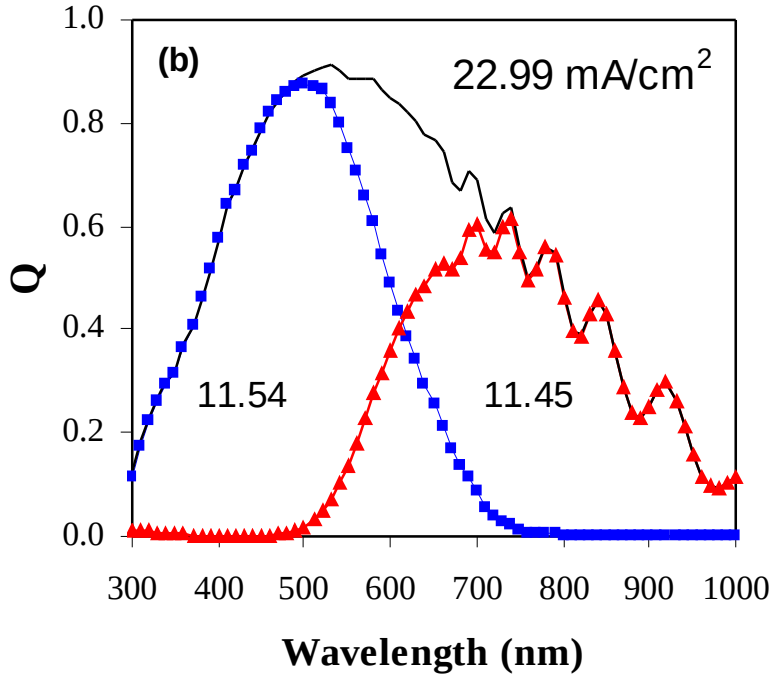
Previous results of a-Si:H/nc-Si:H double-junction solar cells with different bottom cell deposition time.

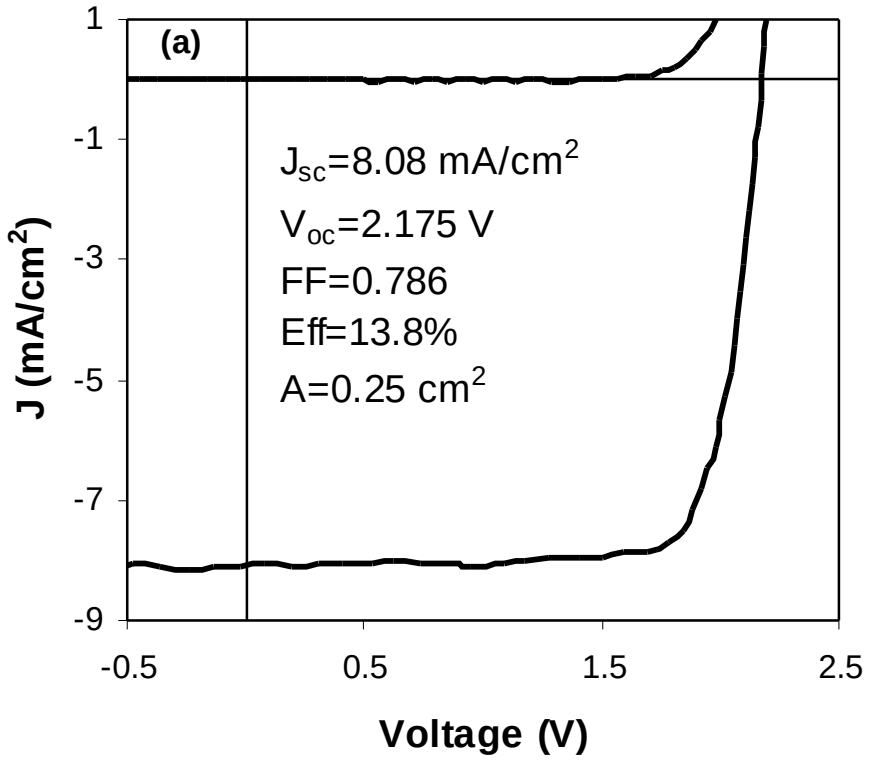
Sample No.	Bottom time (min.)	Eff. (%)	J_{sc} (mA/cm^2)		V_{oc} (V)	FF
			top	bottom		
11569	60	12.04	12.09	12.07	1.359	0.734
11635	50	12.33	11.91	11.99	1.392	0.744
11797	35	11.34	11.77	10.73	1.385	0.763
11835	30	11.35	11.19	11.10	1.406	0.727

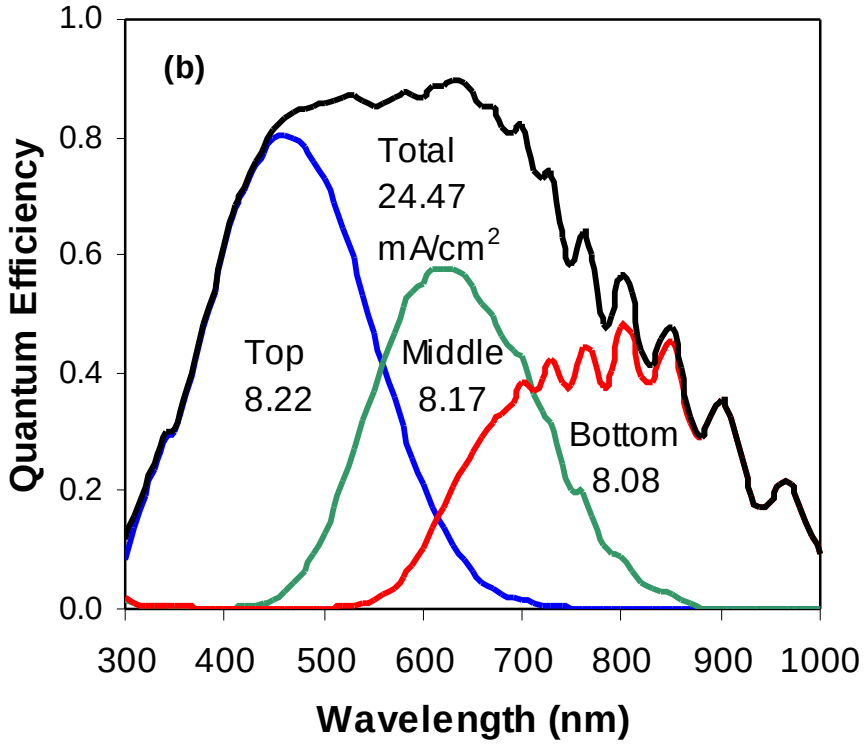
UNI-SOLAR®

a-Si:H/nc-Si:H double-junction cell with bottom cell deposition time of 50 minutes







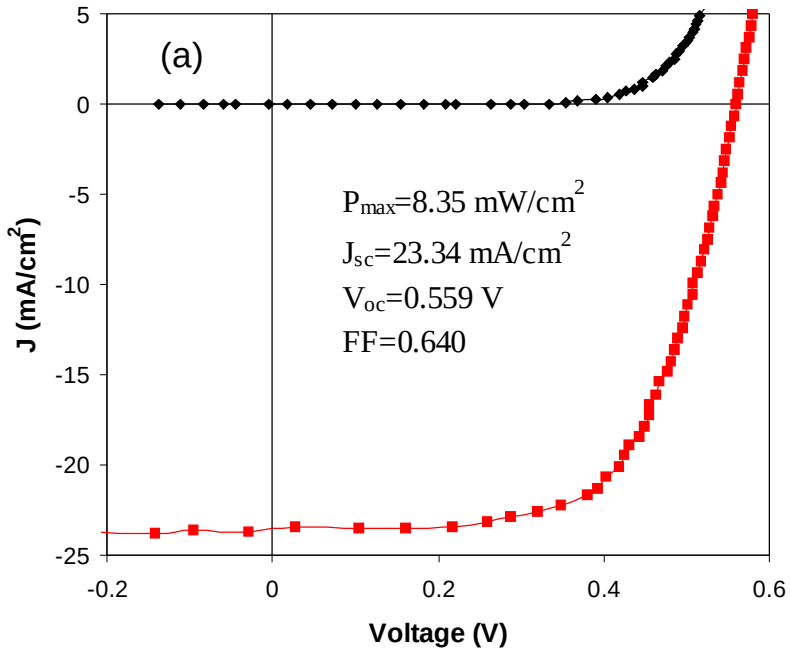


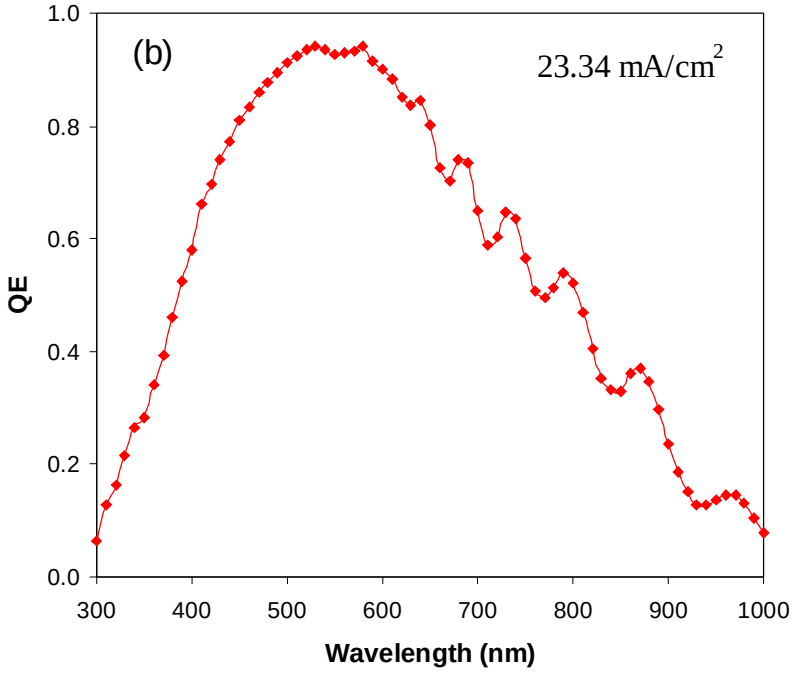
(a) Initial J-V characteristics and (b) quantum efficiency of an a-Si:H/a-SiGe:H/nc-Si:H triple-junction solar cell where the bottom cell was made by MVHF for 50 minutes.

New results with MVHF under high pressure

Typical J-V characteristics of nc-Si:H single-junction solar cells made at high deposition rates

Sample No.	J_{sc} (mA/cm^2)	V_{oc} (V)	FF	P_{max} (mW/cm^2)
13310	23.08	0.564	0.632	8.23
13348	22.72	0.544	0.660	8.16
13461	23.34	0.559	0.640	8.35
13474	23.43	0.558	0.628	8.21
13491	24.88	0.543	0.599	8.09

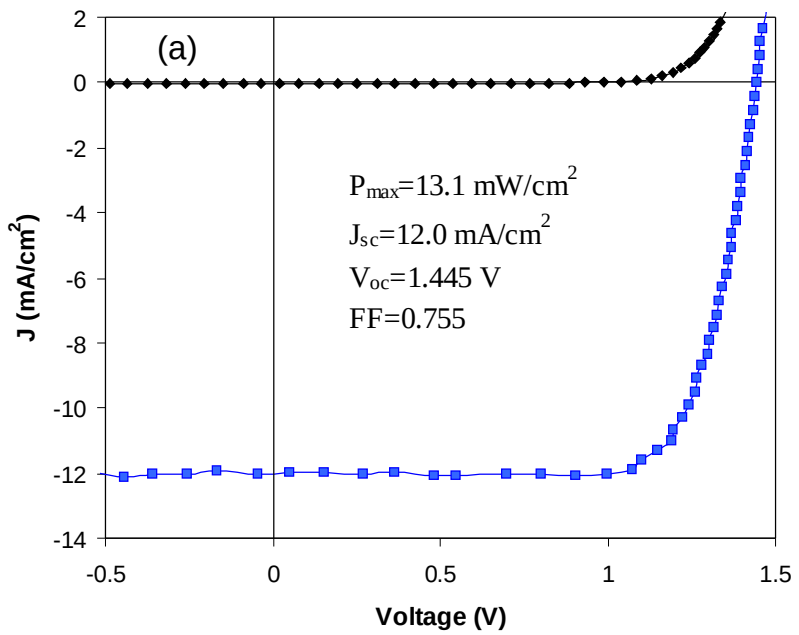


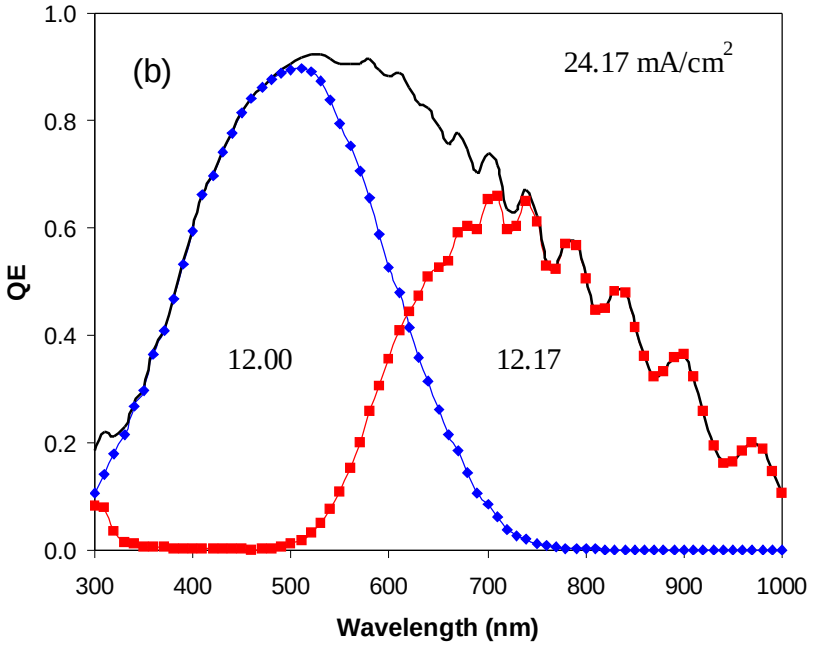


J-V characteristics of a nc-Si:H single-junction cell made with MVHF for 30 minutes of i-layer deposition time

Typical J-V characteristics of a-Si:H/nc-Si:H double-junction solar cells made at high deposition rates with 30 minutes of bottom i-layer deposition time

Sample No.	J_{sc} (mA/cm^2)		V_{oc} (V)	FF	P_{max} (mW/cm^2)
	Top	Bottom			
13520	12.02	12.01	1.434	0.749	12.9
13528	12.00	12.17	1.445	0.755	13.1
13536	12.28	12.12	1.444	0.741	13.0





J-V characteristics of an a-Si:H/nc-Si:H double-junction cell made with MVHF for **10** and **30** minutes of the top and bottom cell i-layers deposition time, respectively.

UNI-SOLAR®

Key techniques for achieving high efficiency a-Si:H/nc-Si:H double-junction cells

1. **Optimized nc-Si:H single-junction cell**

- Hydrogen dilution profiling to control the microstructure evolution
- Proper treatment at the *n/i* and *i/p* interfaces
- Optimized doped layers

2. **Optimized a-Si:H top cell**

- Proper hydrogen dilution to control the a-Si:H close to but not over the transition to nanocrystalline regime

Summary and future work

1. We have achieved an initial active-area efficiency of **8.3%** using a nc-Si:H single-junction cell with 30 minutes of *i*-layer deposition time
2. We have achieved an initial active-area efficiency of **13.1%** using an a-Si:H/nc-Si:H double-junction cell with 10 and 30 minutes of the top and bottom cell *i*-layers deposition time
3. We are currently in the process of improving the cell efficiency further by optimizing the plasma parameters and cell structure
4. We are going to investigate the large-area deposition with MVHF at high rates

Thanks for the financial support from NREL and various technical supports from the team members